METERING LEADER SINCE 1904

TESCO

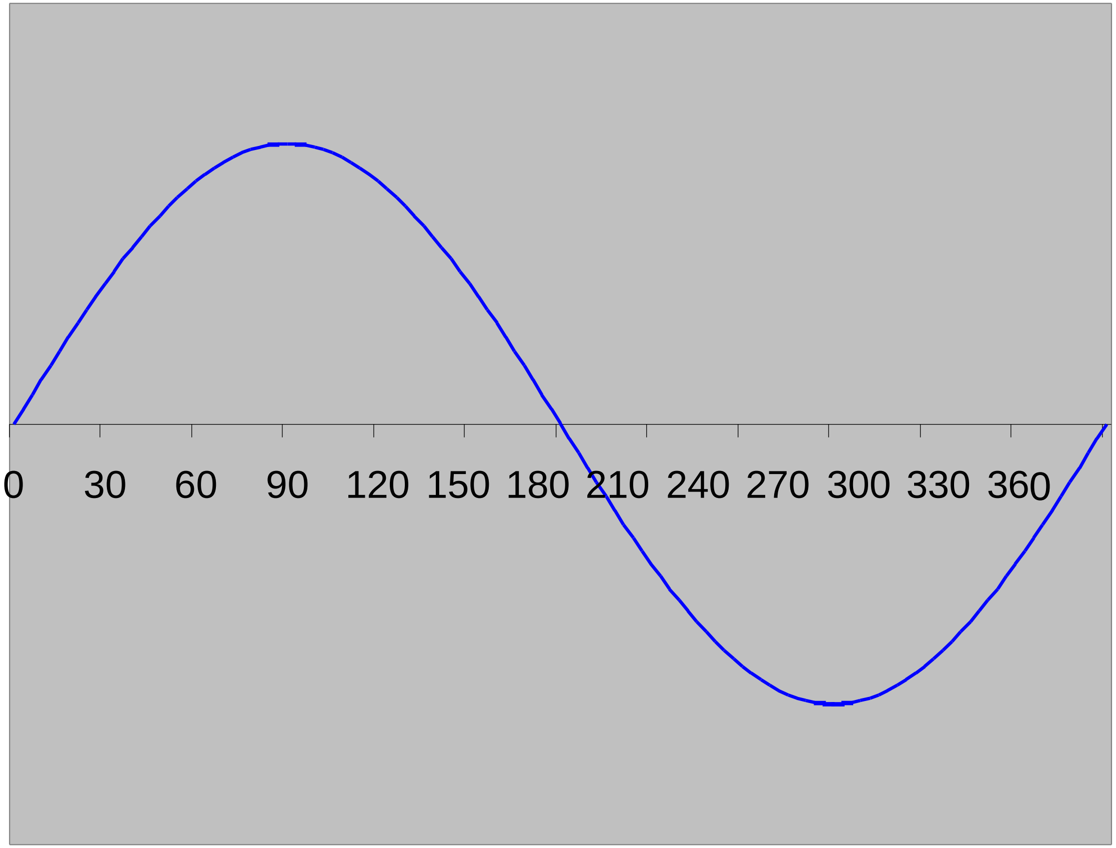
THE EASTERN SPECIALTY COMPANY

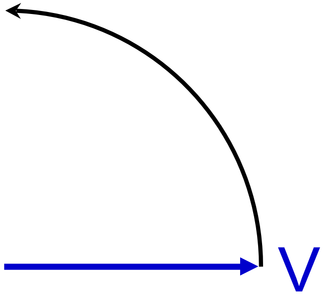
Introduction to Polyphase Metering

Prepared by Tom Lawton, TESCO
The Eastern Specialty Company

For Mid-South Meter School
Group 2
Wednesday, May 3, 2023 at 10:00 AM

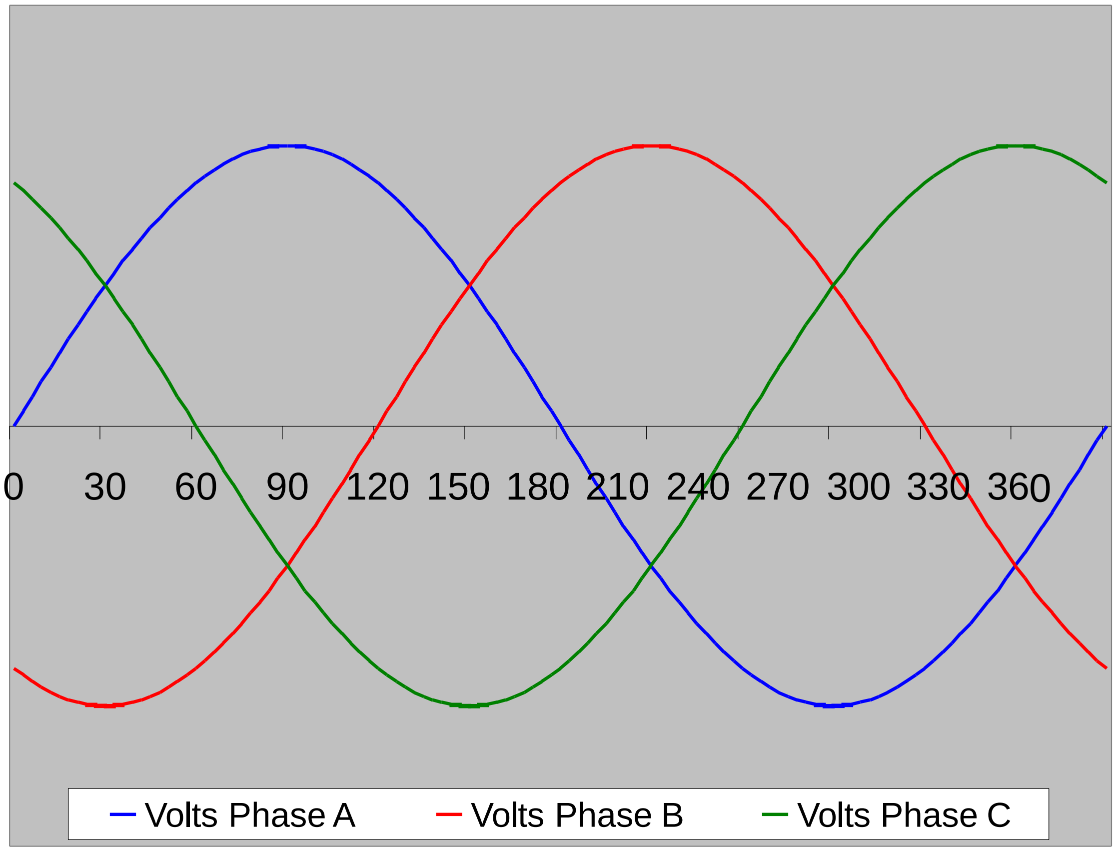
1-Phase and 3-Phase Power

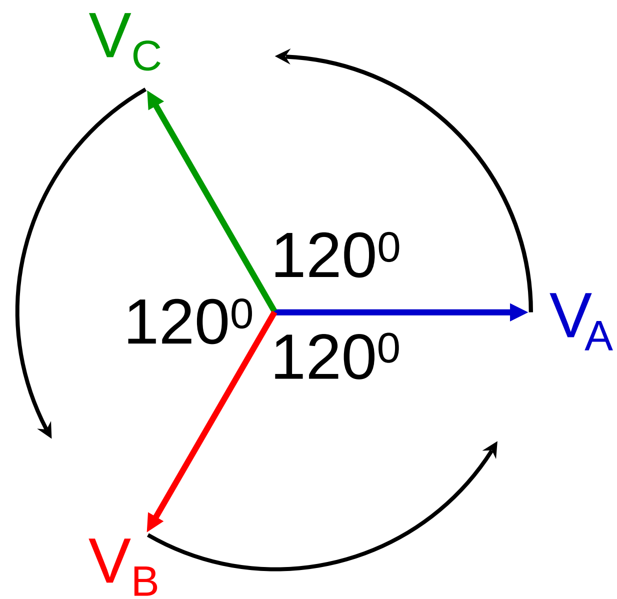




Voltage = V_{max} sine α

1-PHASE AND 3-PHASE POWER





Forward Rotation, ABC

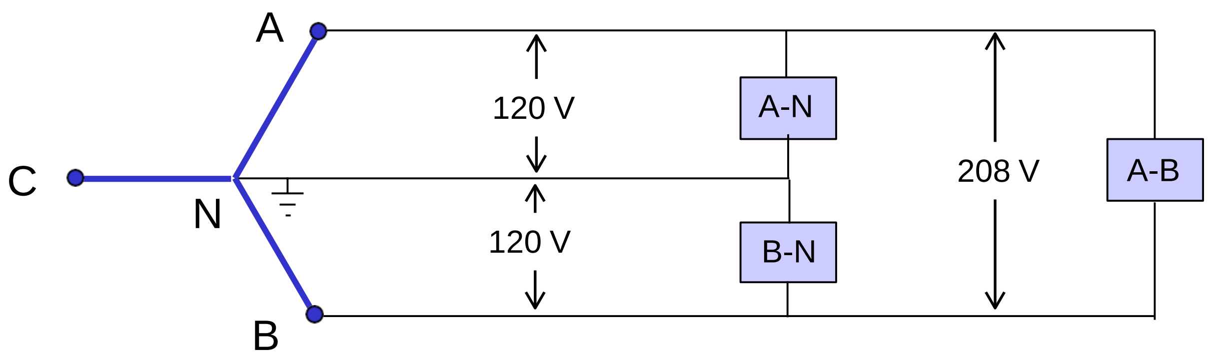
The Need for 3-Phase Power

Single-phase motors provide a pulsating torque to a mechanical load. Loads which require more than 10 horsepower generally also require the steadier torque of a 3-phase motor.

Benefits of 3-Phase Power

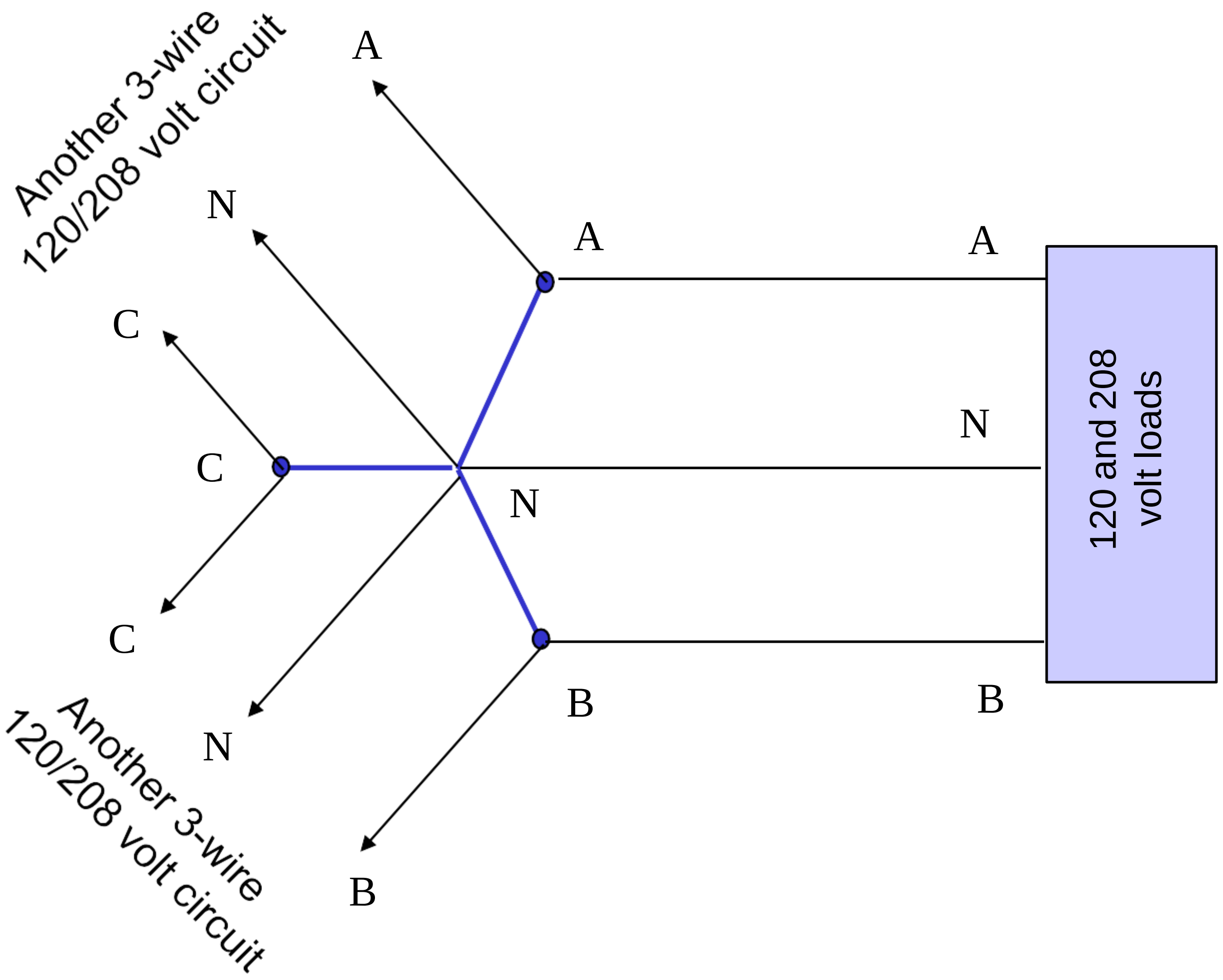
- ✓Steadier motor torque
- ✓Less vibration in machinery
- ✓Greater mechanical efficiency
- ✓Better voltage regulation
- ✓Lower heat losses
- ✓Lighter weight conductors

Network Service & Loads

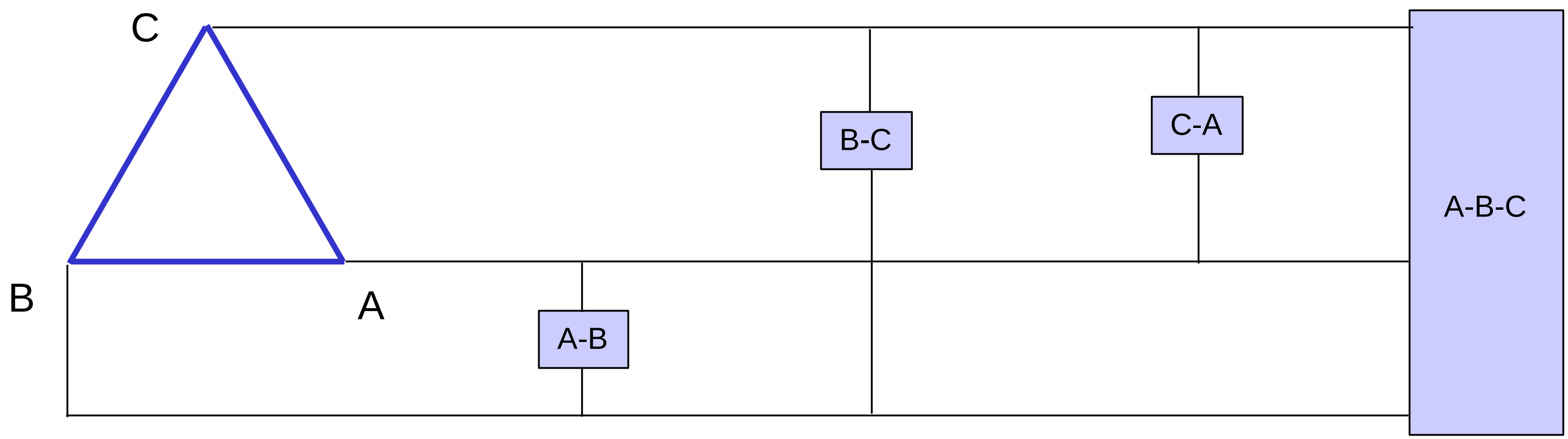


Need to meter line-neutral and line-line loads.

Network Service & Loads

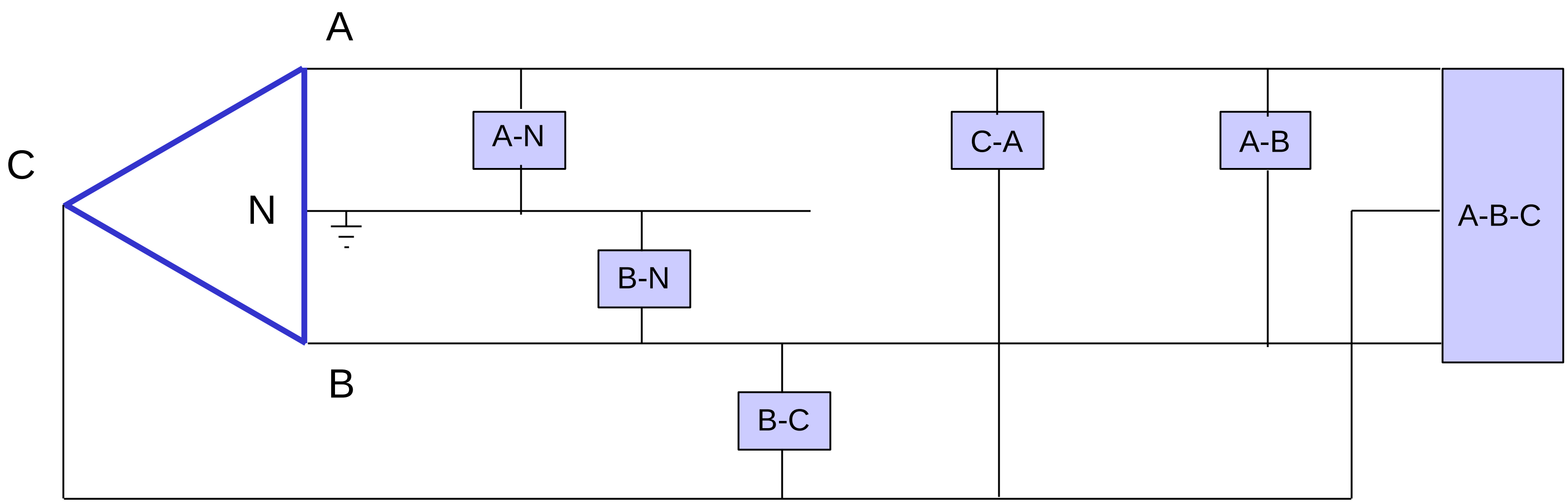


3-Wire Delta Service & Loads



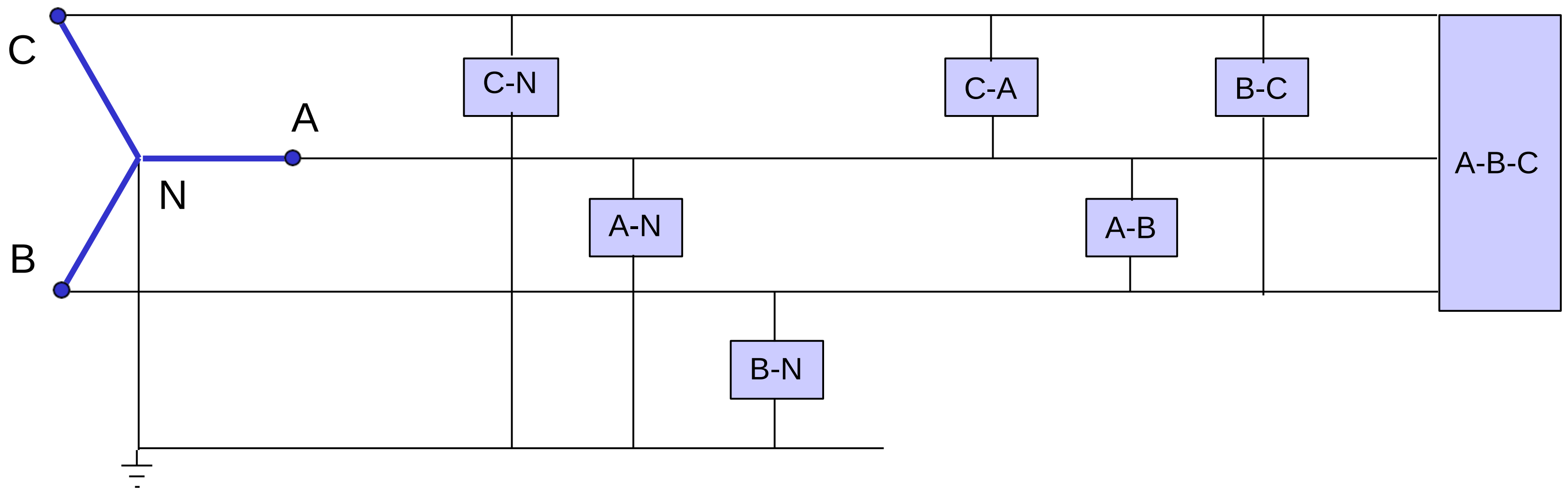
Need to meter single phase line-line loads, as well as three phase loads.

4-Wire Delta Service & Loads



Need to meter single phase line-neutral and line-line loads, as well as three phase loads.

4-Wire Wye Service & Loads



Need to meter single phase line-neutral and line-line loads, as well as three phase loads.

Blondel's Theorem

Blondel says:

If energy is supplied to any system of conductors through N wires, the total power in the system is given by the algebraic sum of readings of N wattmeters, so arranged that each of the N wires contains one current coil, the corresponding potential coil being connected between that wire and some common point. If this common point is on one of the N wires, the measurement may be made by the use of N-1 wattmeters.

Andre E. Blondel, 1893

- We would use "watthour meters" in place of "watt meters" and "energy" in place of "power".
- We would also consider "ground" as a possible current carrying conductor when counting "N".

Blondel's Theorem

- In a system of N conductors, N-1 meter elements, properly connected, will measure the power or energy taken. The connection must be such that all voltage coils have a common tie to the conductor in which there is no current coil.[1]

[1] From the Handbook For Electricity Metering, 9th edition.

What is a Meter Form Number?

- A Form designation tells us:
  - The number and arrangement of meter terminals, and
  - The number and ***internal connection*** of meter elements (stators).
- The Form designation describes the meter, not the service.
  - With modern meters, some meter Forms may be used to correctly meter more than one service configuration.
  - More than one meter Form could be used with a particular service depending on the connection of the Instrument Transformers.
- The same Form designation is usually applicable to equivalent meters of all manufacturers.

Will's Meter Forms Cheat Sheet

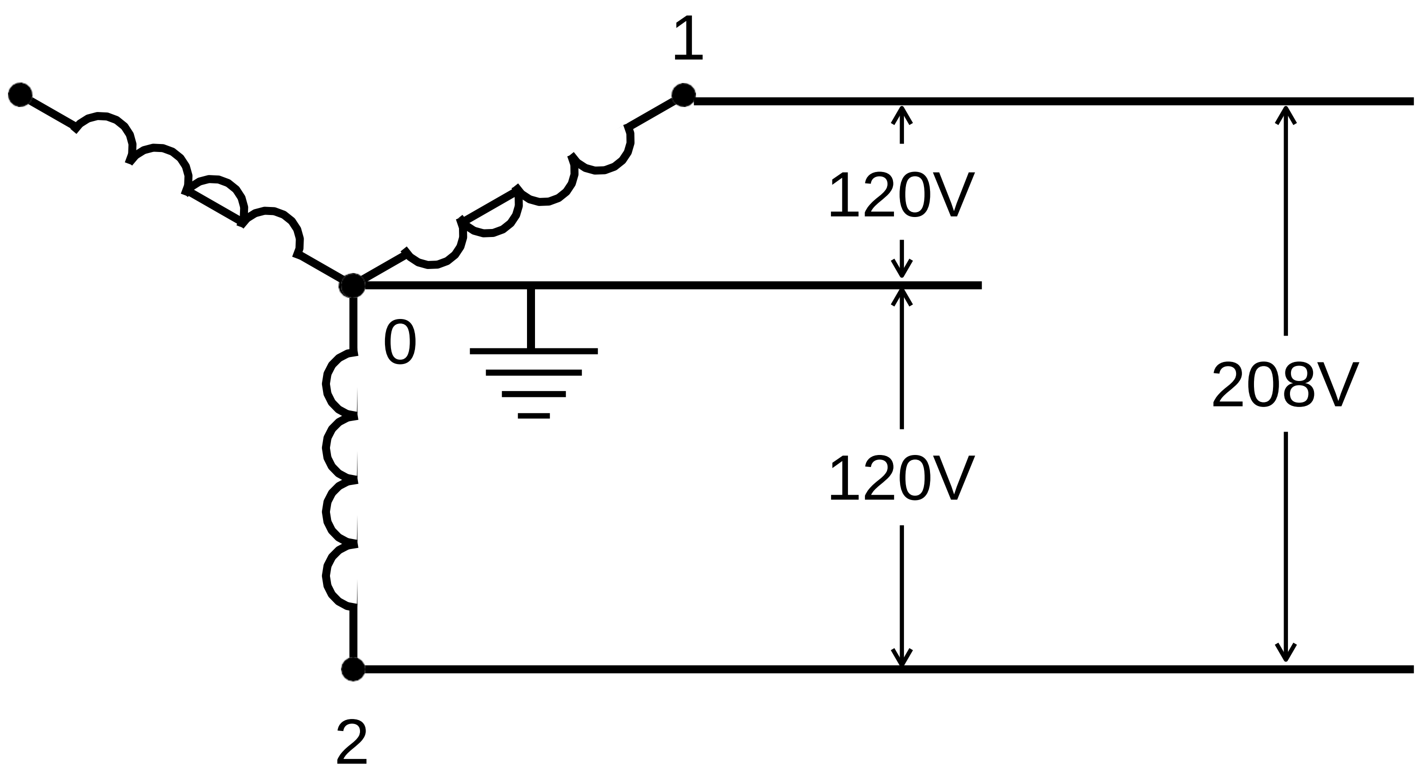
<table>
<tr><th>SERVICE</th><th>SELF-CONT FORM</th><th>XFMR-RATD FORM</th><th>NUMBER OF ELEMENTS</th></tr>
<tr><td>1-Phase, 2-Wire</td><td>1S</td><td>3S</td><td>1</td></tr>
<tr><td>1-Phase, 3-Wire</td><td>2S</td><td>4S</td><td>1.5</td></tr>
<tr><td>Network, 3-Wire</td><td rowspan="2">12S</td><td rowspan="2">5S / 45S</td><td rowspan="2">2</td></tr>
<tr><td>3-Phase, 3-Wire, Delta</td></tr>
<tr><td>3-Phase, 4-Wire, Delta</td><td>15S</td><td>8S</td><td rowspan="2">2.5</td></tr>
<tr><td rowspan="2">3-Phase, 4-Wire, Wye</td><td>14S</td><td>6S / 36S</td></tr>
<tr><td>16S</td><td>9S</td><td>3</td></tr>
</table>

Consolidated by kV2c Form 16S

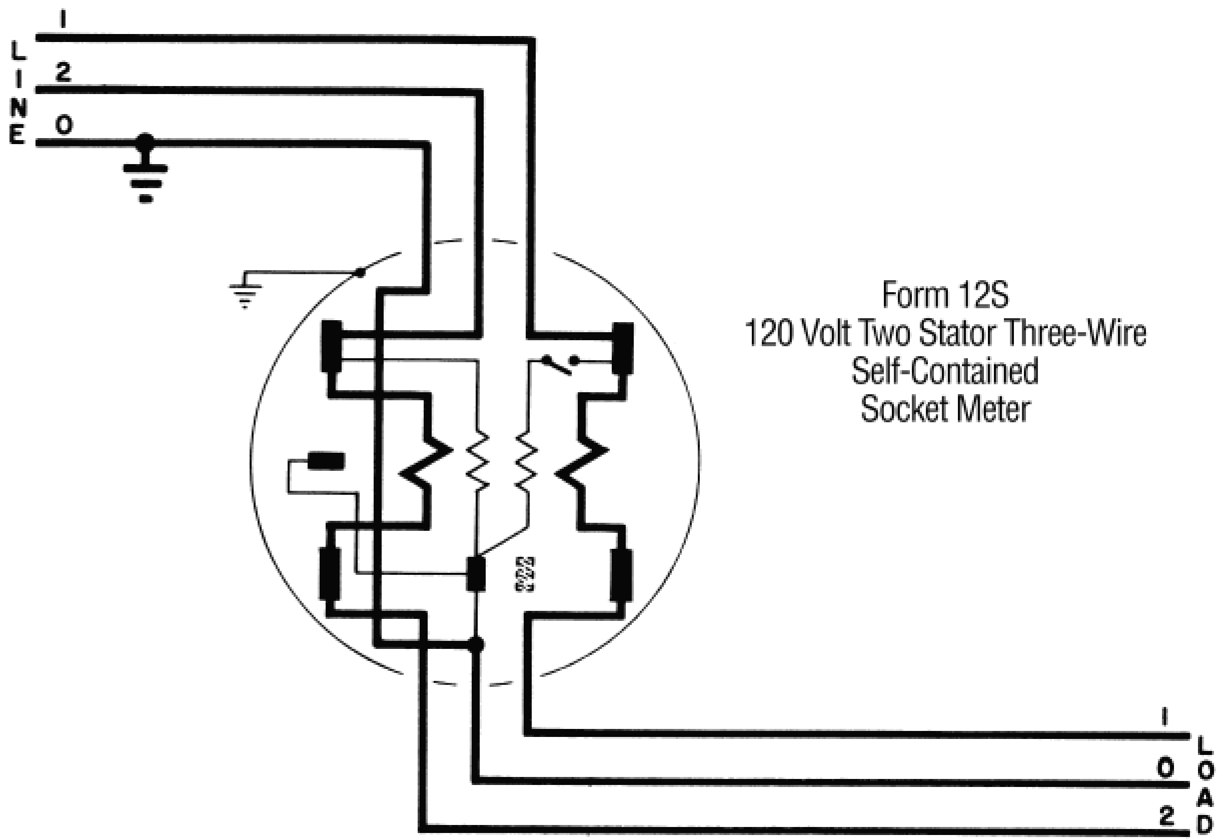
Consolidated by kV2c Form 9S

Blondel Solution

Network, 3-Wire

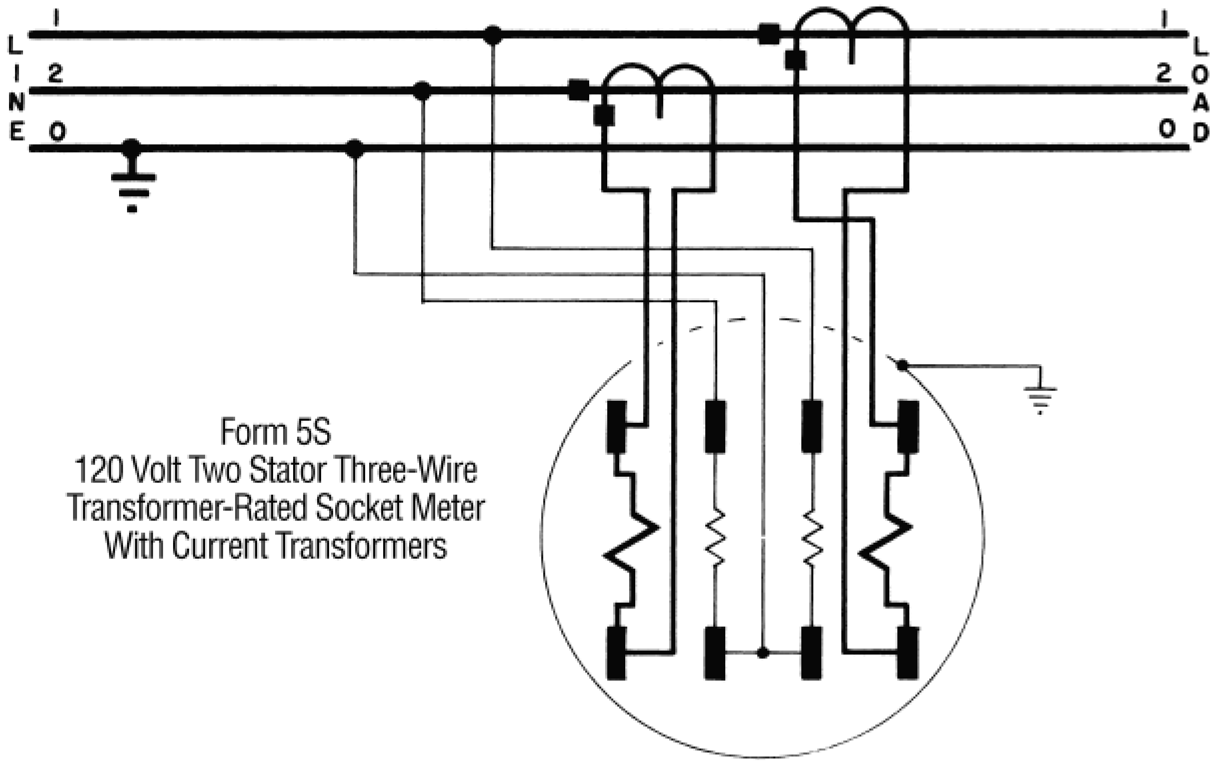


Network, 3-Wire



Form 12S
120 Volt Two Stator Three-Wire
Self-Contained
Socket Meter

Network, 3-Wire



Form 5S
120 Volt Two Stator Three-Wire
Transformer-Rated Socket Meter
With Current Transformers

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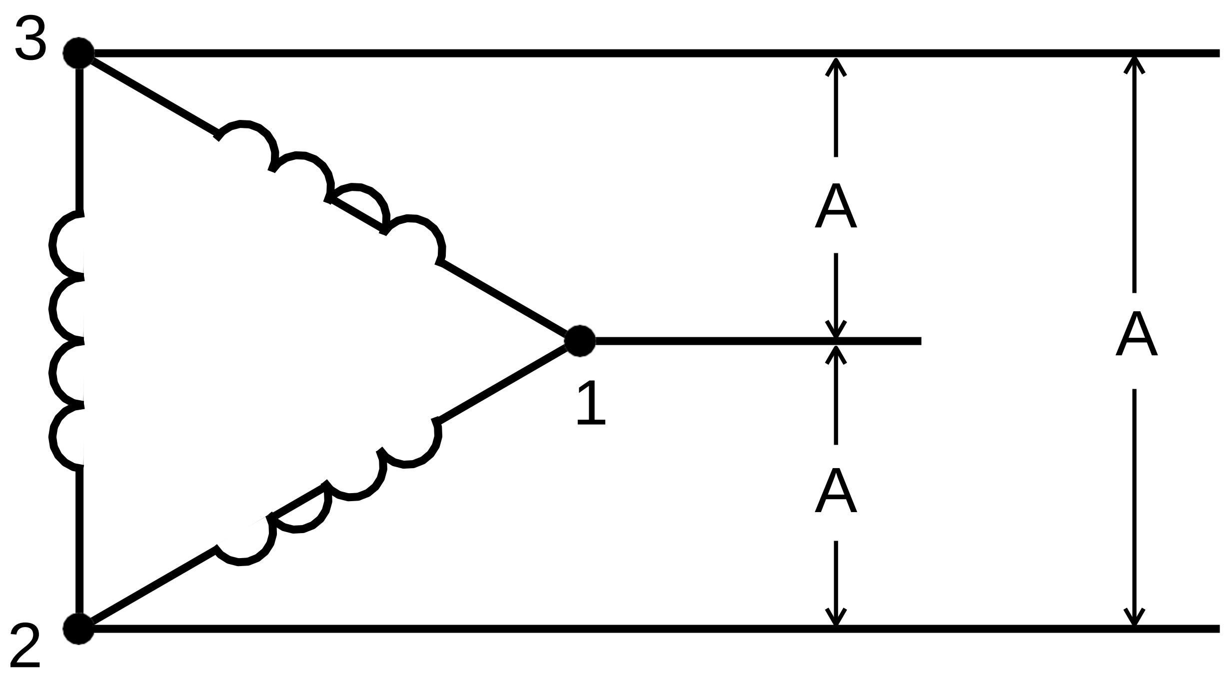
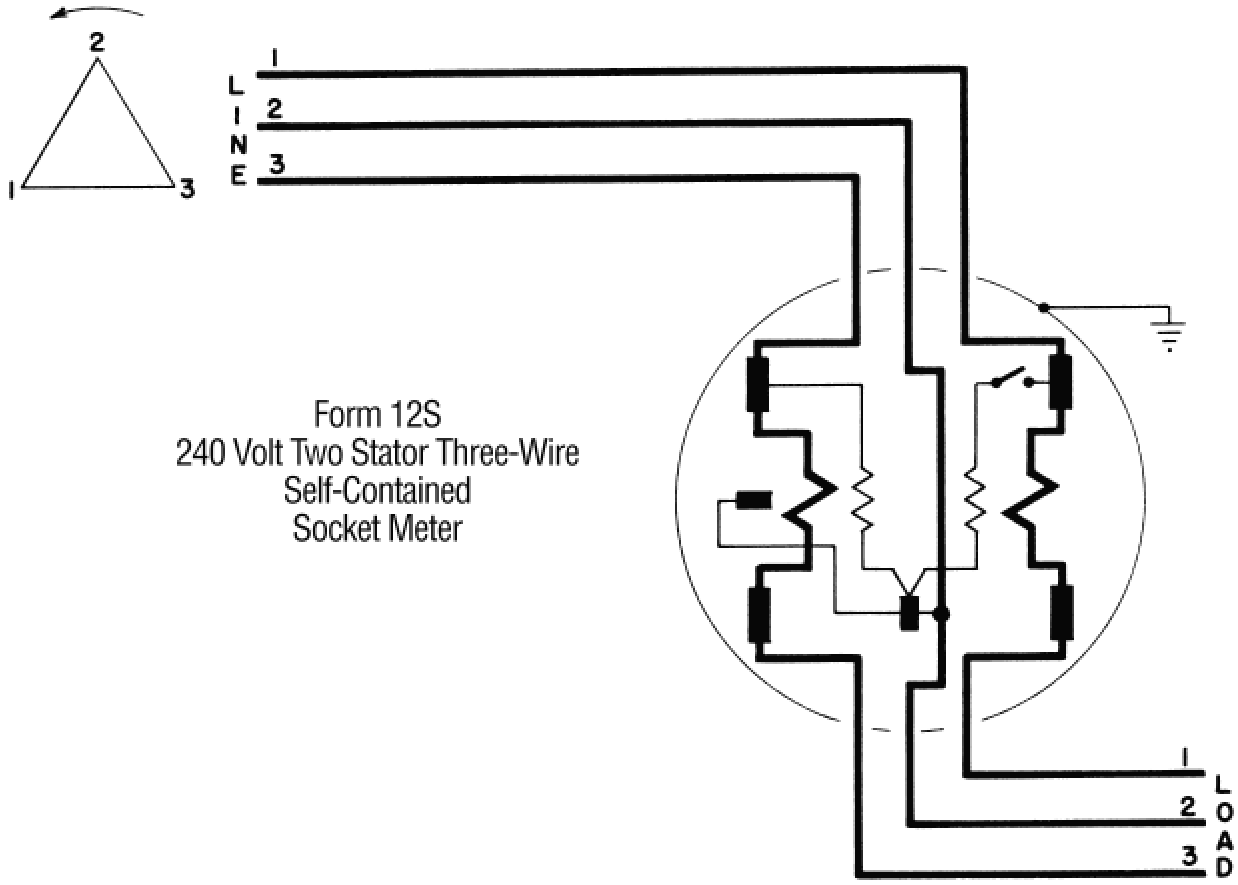
3-Phase, 3-Wire, Delta

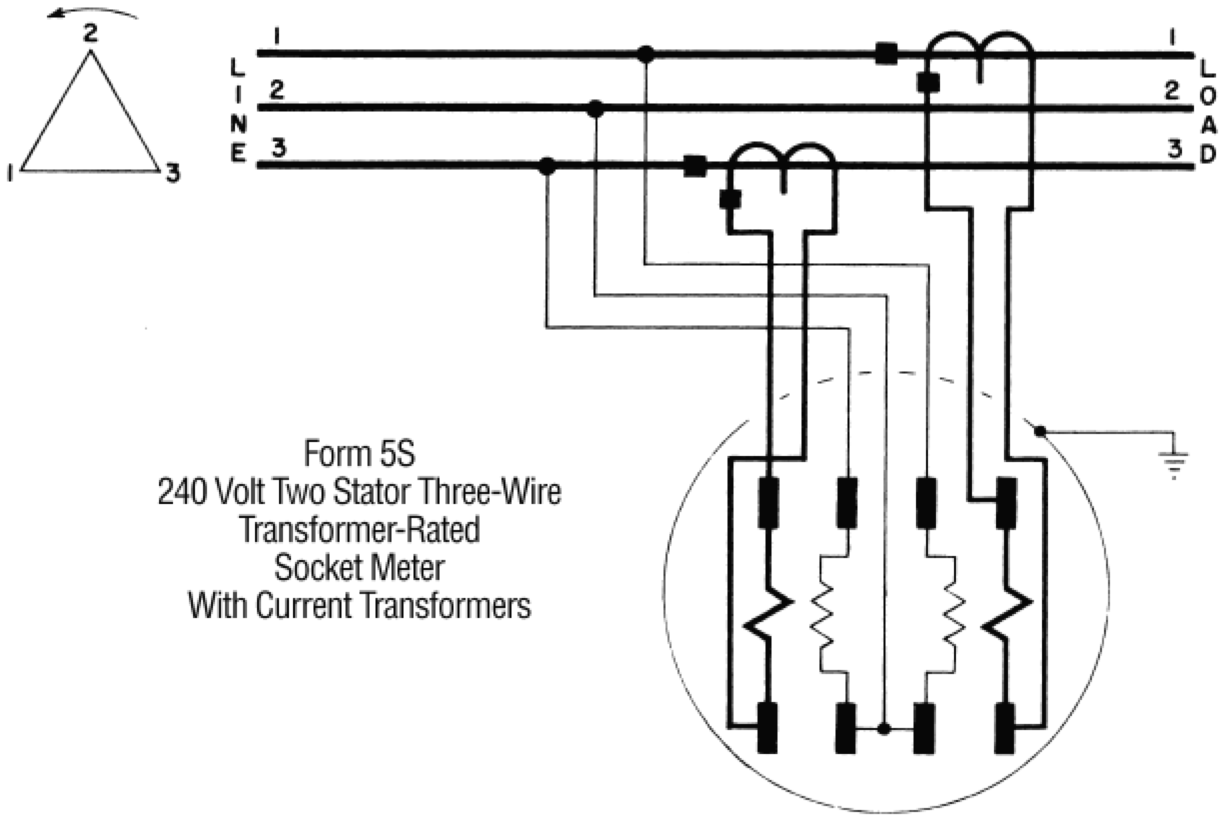


A = 120V, 240V, or 480V

3-Phase, 3-Wire, Delta

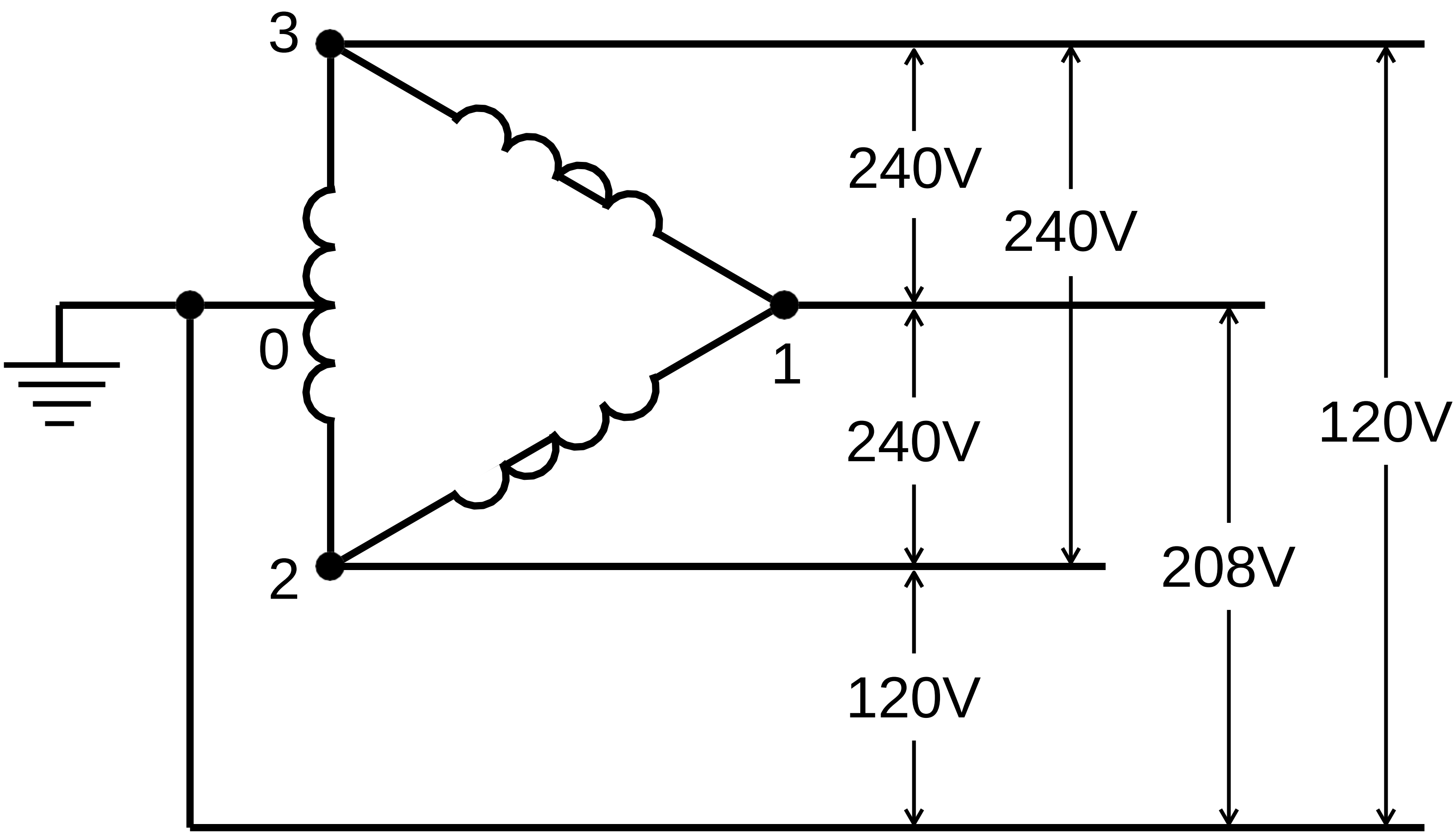


3-Phase, 3-Wire, Delta



Form 5S
240 Volt Two Stator Three-Wire
Transformer-Rated
Socket Meter
With Current Transformers

3-Phase, 4-Wire, Delta



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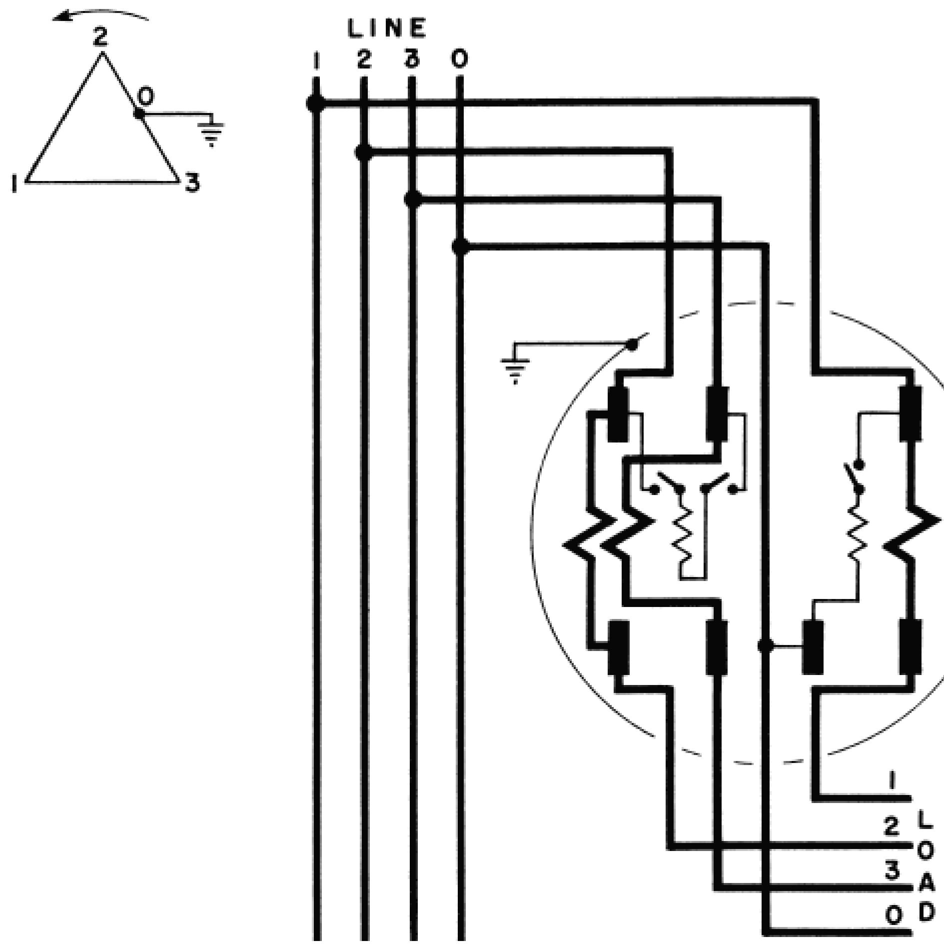
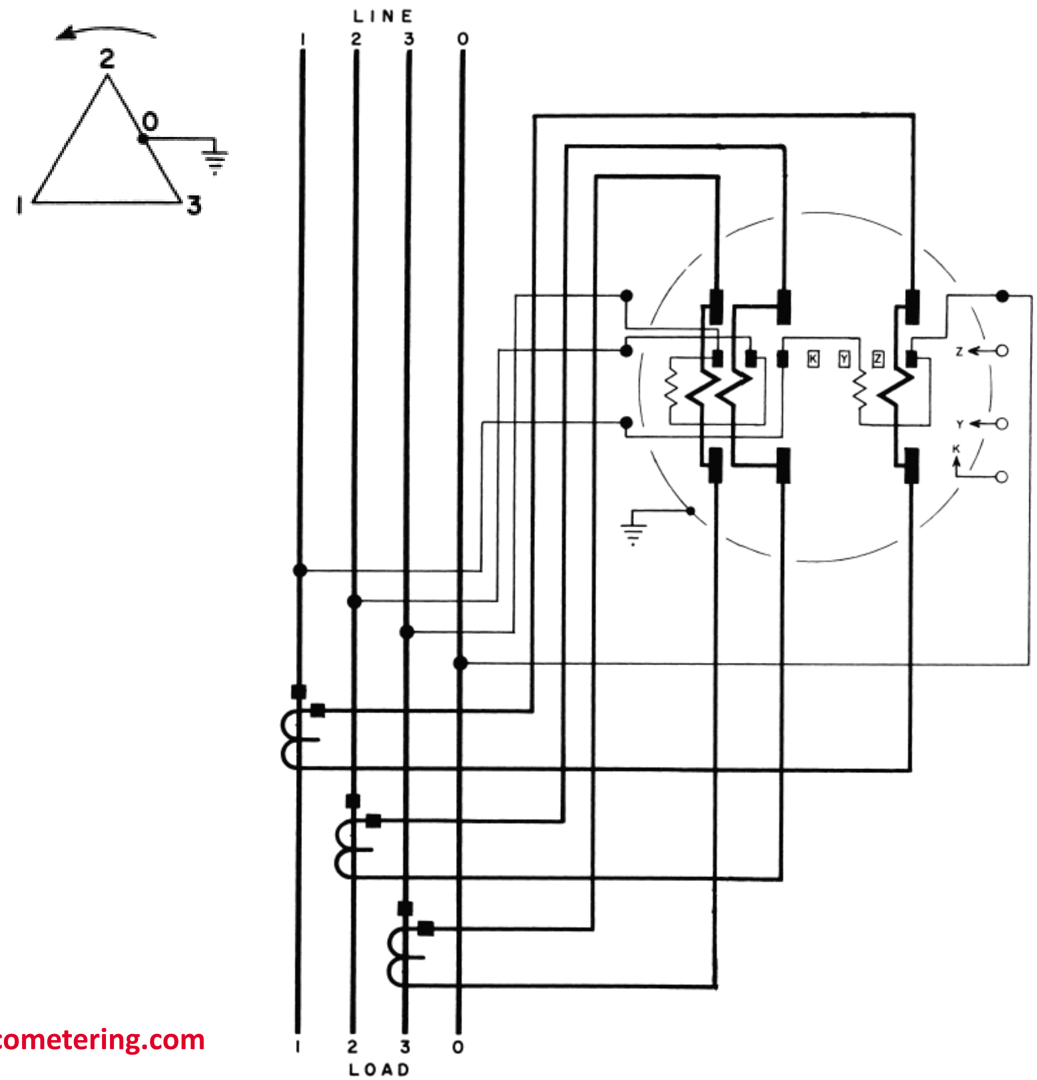
3-Phase, 4-Wire, Delta



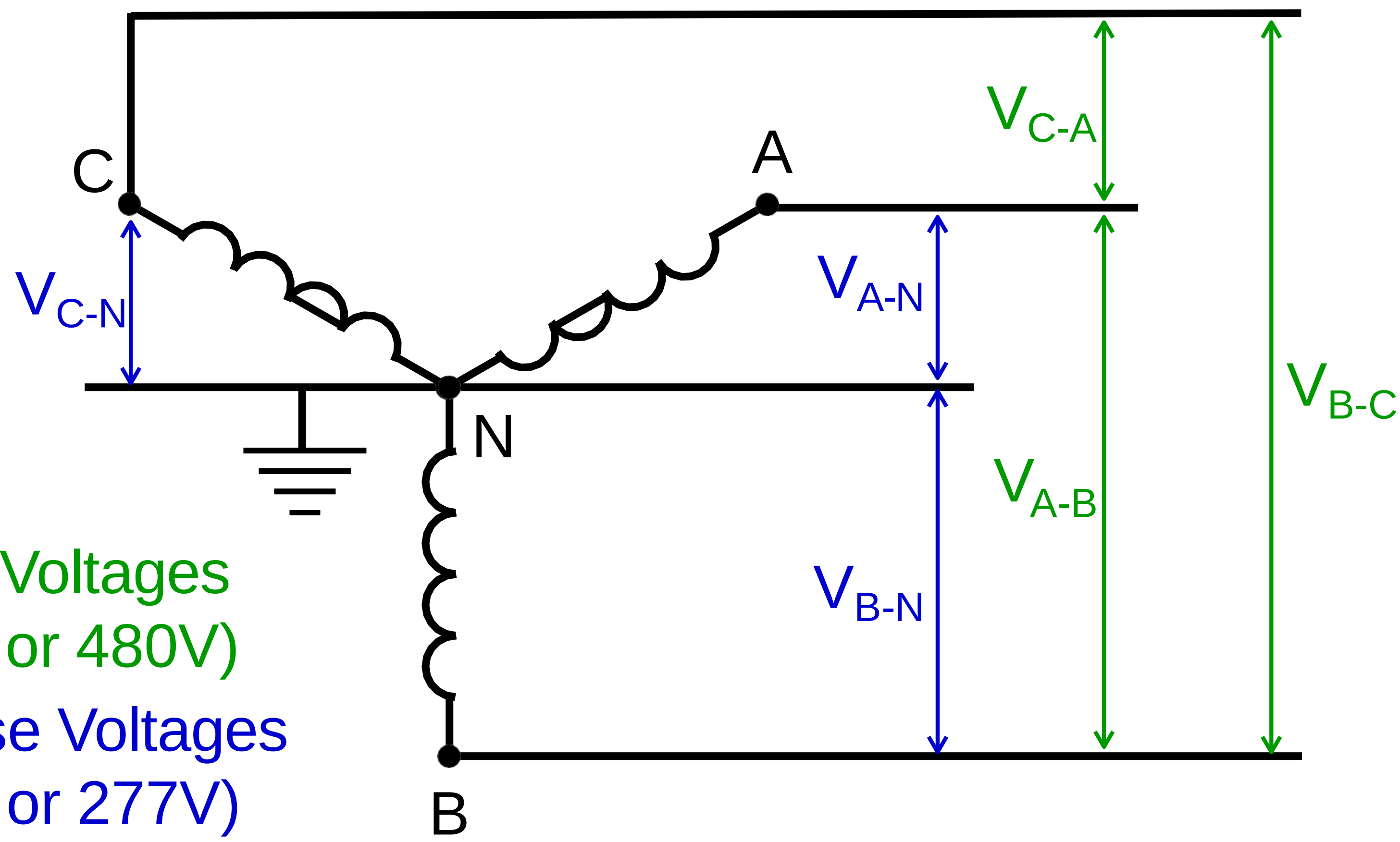
Form 15S
240 Volt Two Stator Four-Wire
Self-Contained
Socket Meter

3-Phase, 4-Wire, Delta



Form 8S
240 Volt Two Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

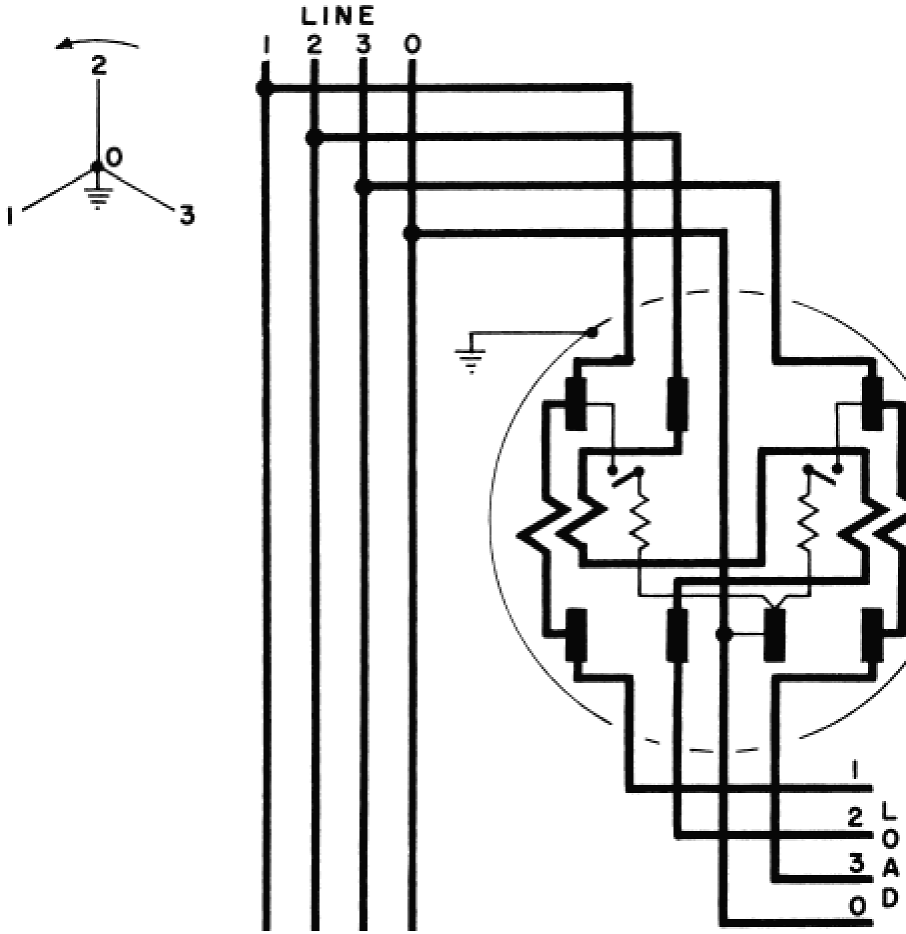
3-Phase, 4-Wire, Wye



Line Voltages
(208 or 480V)

Phase Voltages
(120 or 277V)

3-Phase, 4-Wire, Wye



Form 14S
120 Volt Two Stator Four-Wire
Self-Contained
Socket Meter

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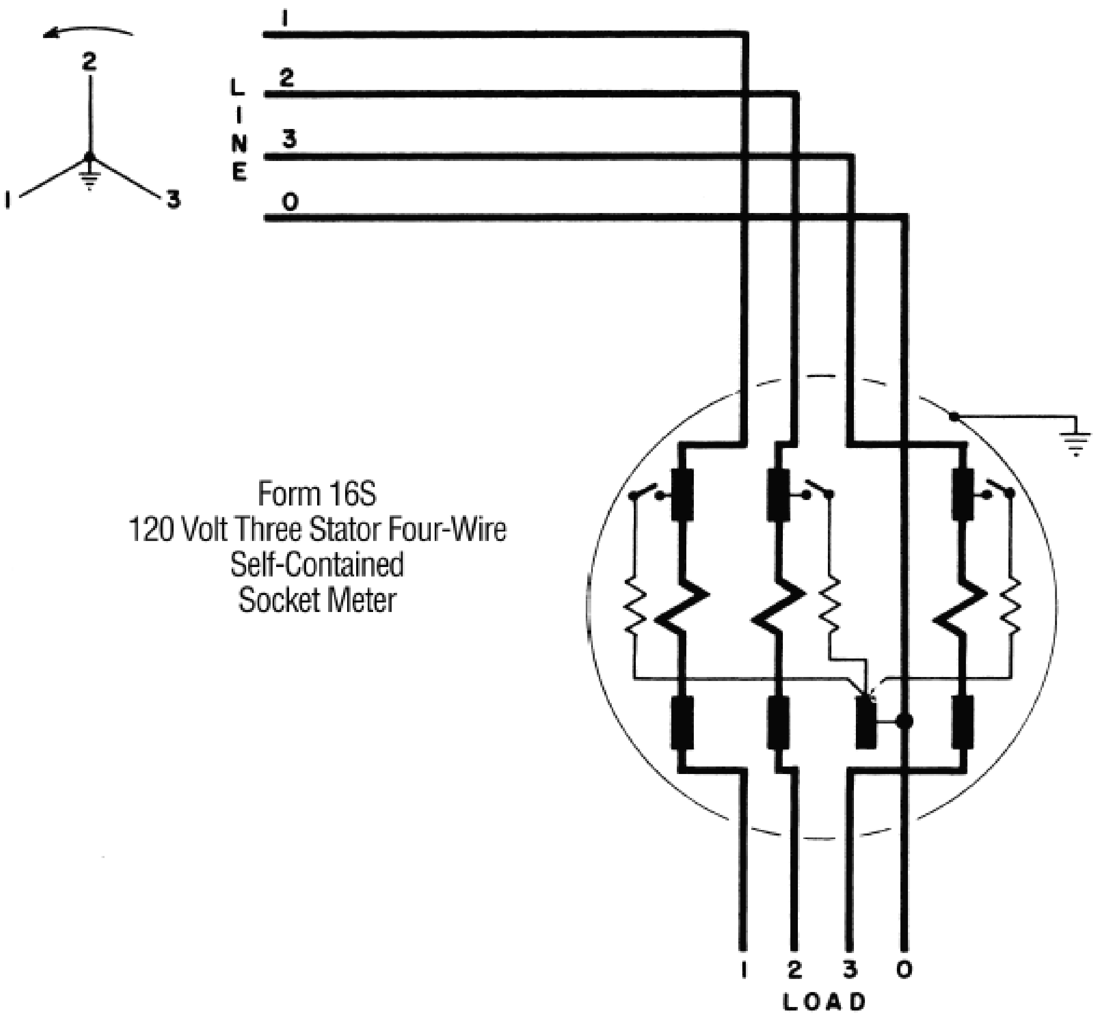
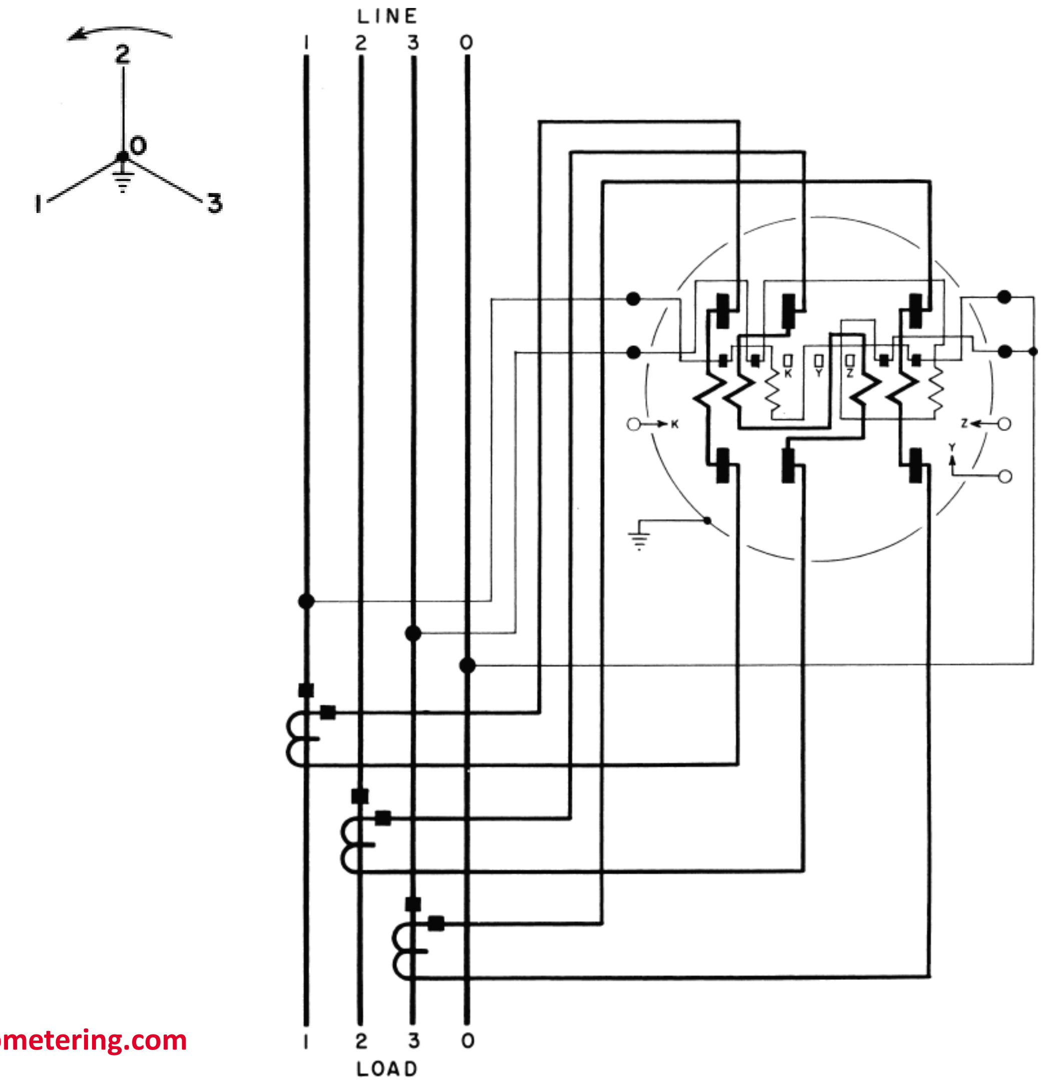
3-Phase, 4-Wire, Wye



Form 16S
120 Volt Three Stator Four-Wire
Self-Contained
Socket Meter

3-Phase, 4 Wire, Wye



Form 6S
120 Volt Two Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

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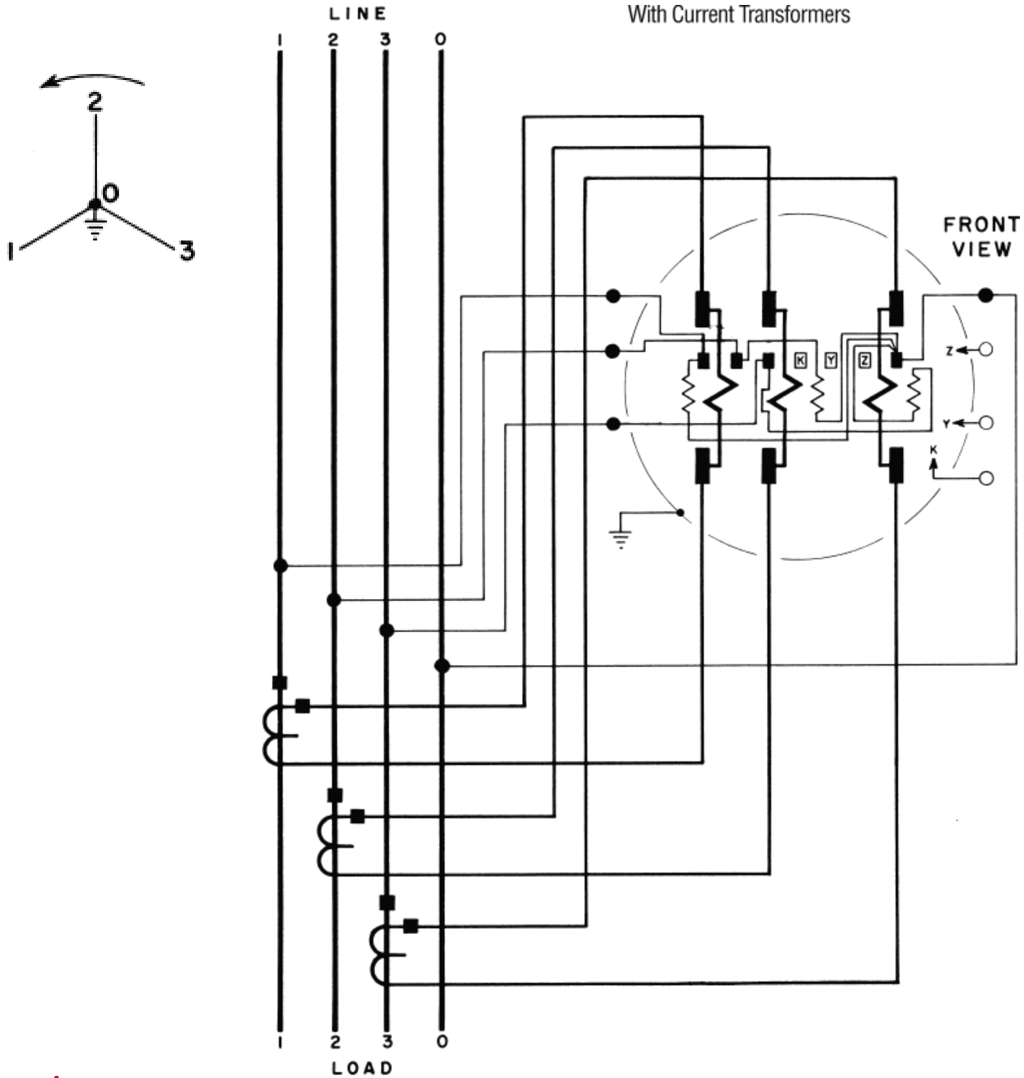
3-Phase, 4-Wire, Wye



Form 9S
120 Volt Three Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

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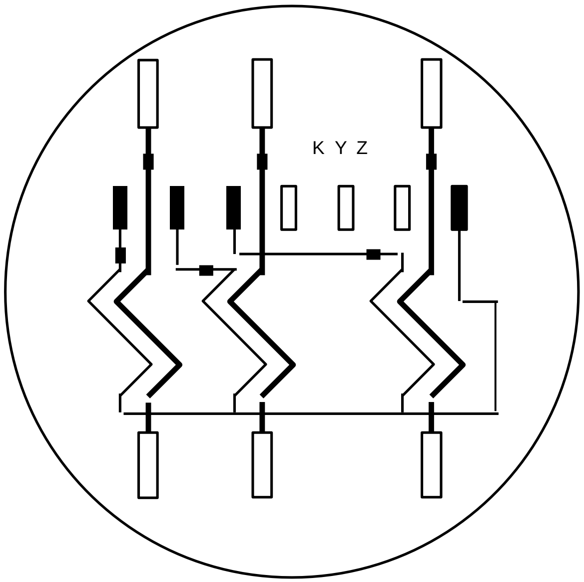
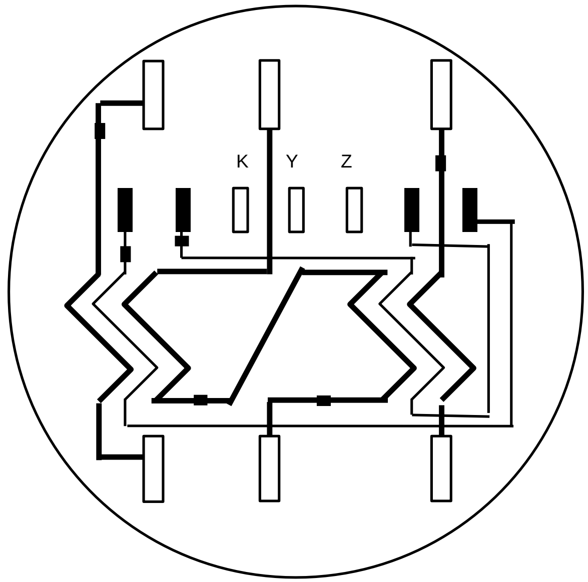
4-Wire Wye Metering



Form 9

3 Element,

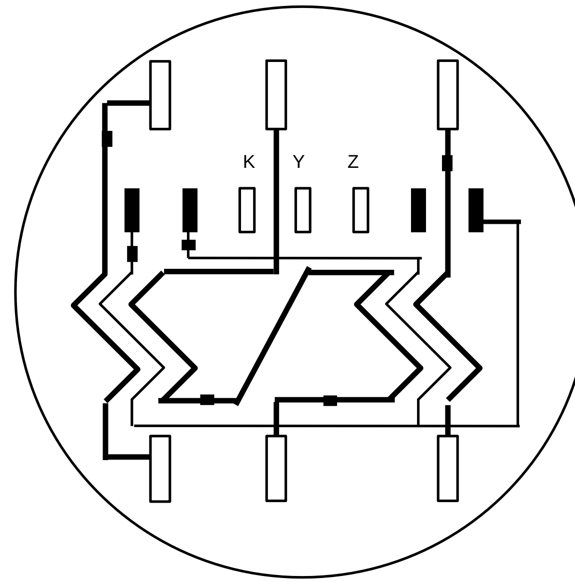
4 wire, wye



Form 6

2½ Element,

4 wire, wye



Form 36

2½ Element,

4 wire, wye

Transformer-rated

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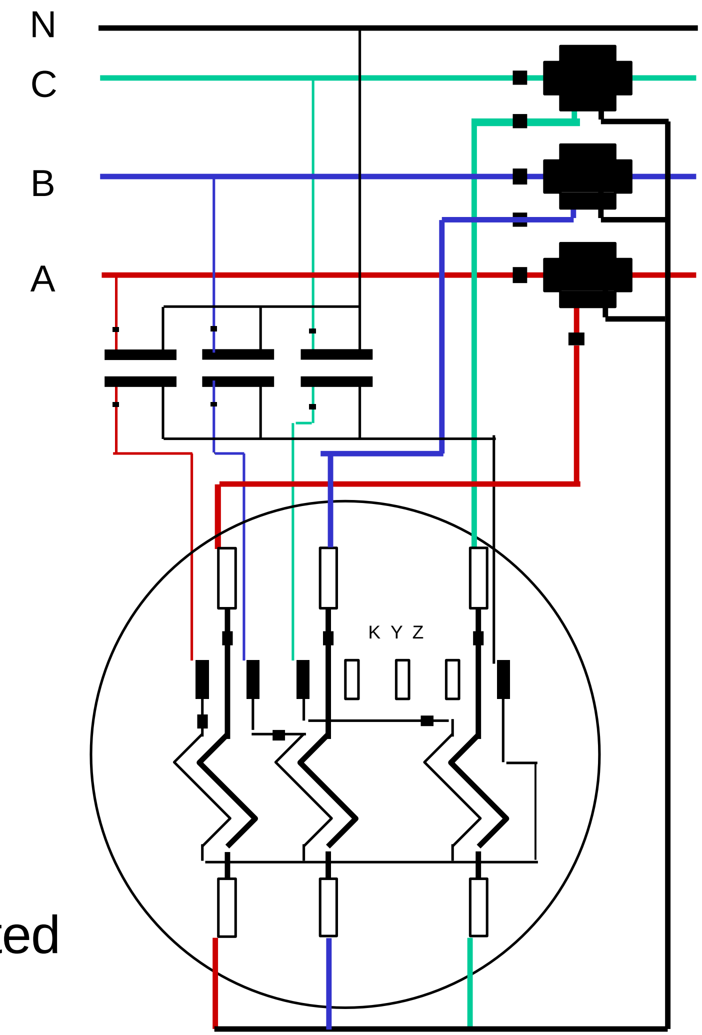
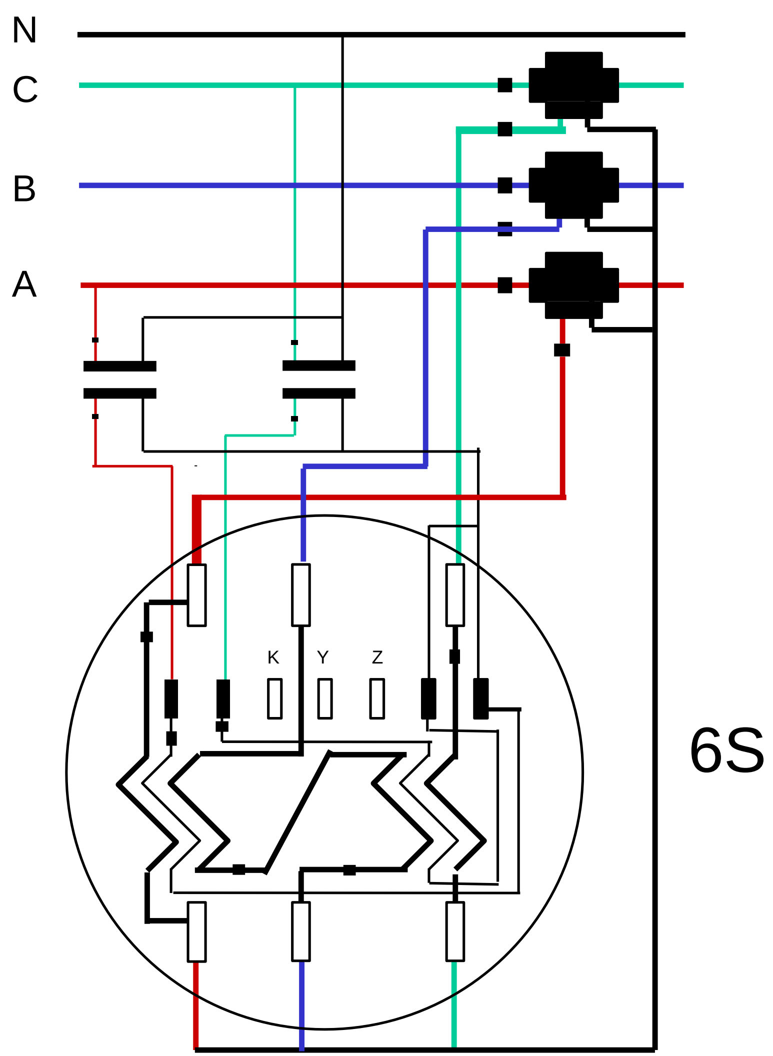
4-Wire, Wye Metering



9S

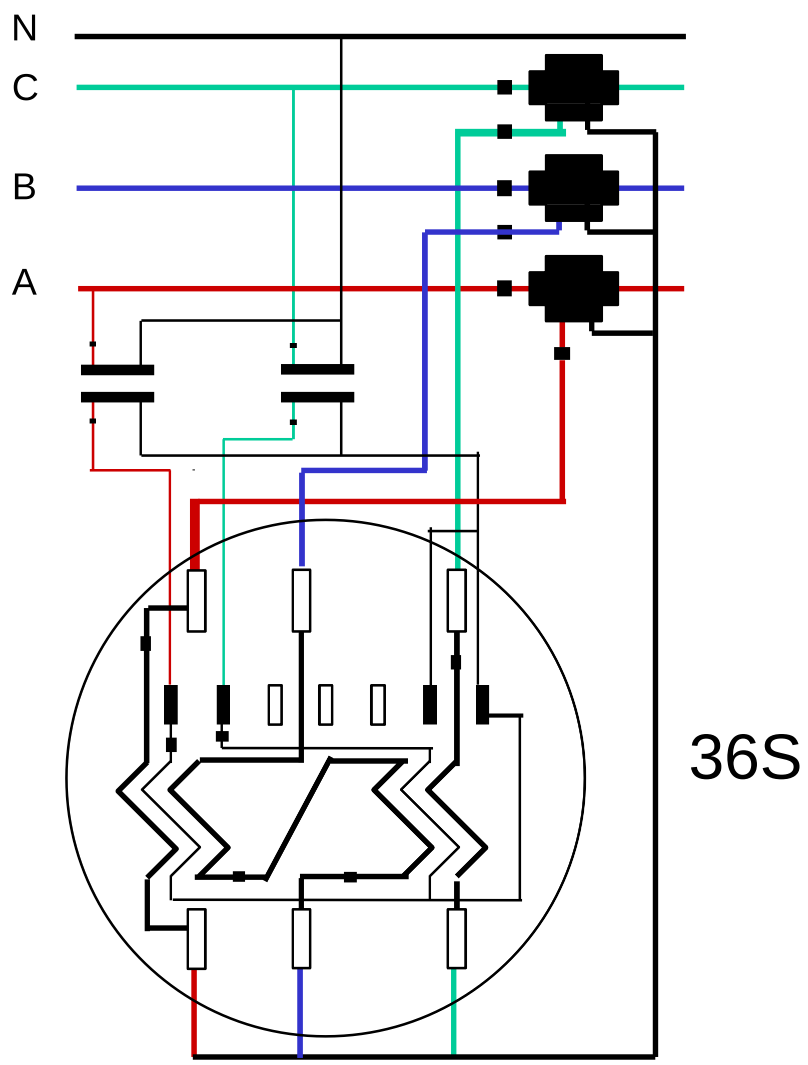
Transformer-rated

4-Wire, Wye Metering



Transformer-rated

4-Wire, Wye Metering



Transformer-rated

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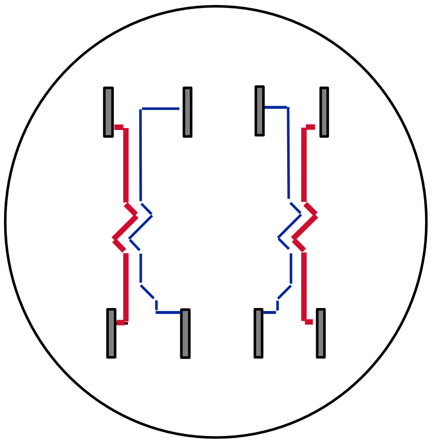
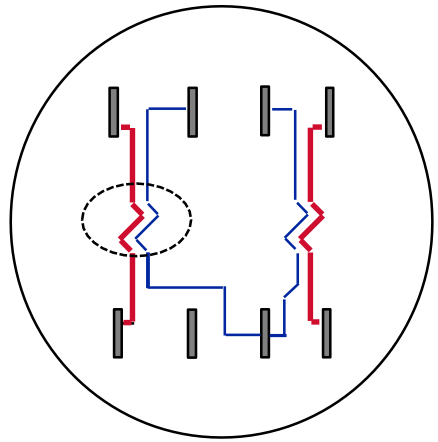
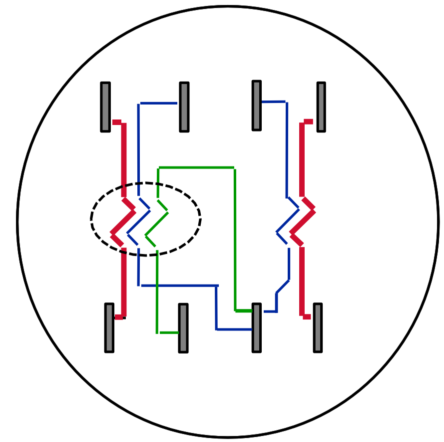
2 Element Meters



Form 5



Form 35



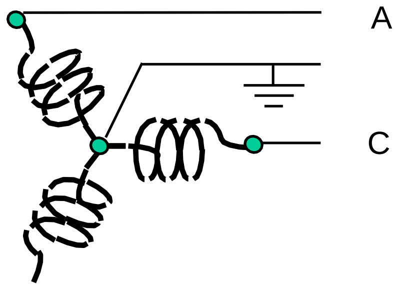
Form 45

Typically used for 3 wire Network or 3 wire, 3 phase Delta applications

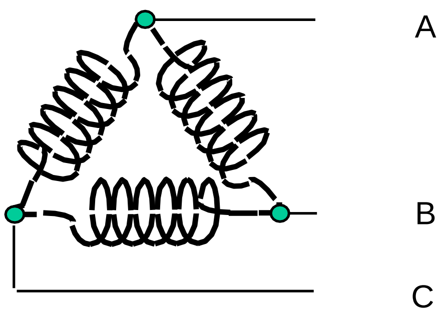
Occasionally used for other service types including 2 wire single phase, 4 wire Wye and 4 wire Delta (except Fm 35 not for 4W Delta)

Transformer-rated

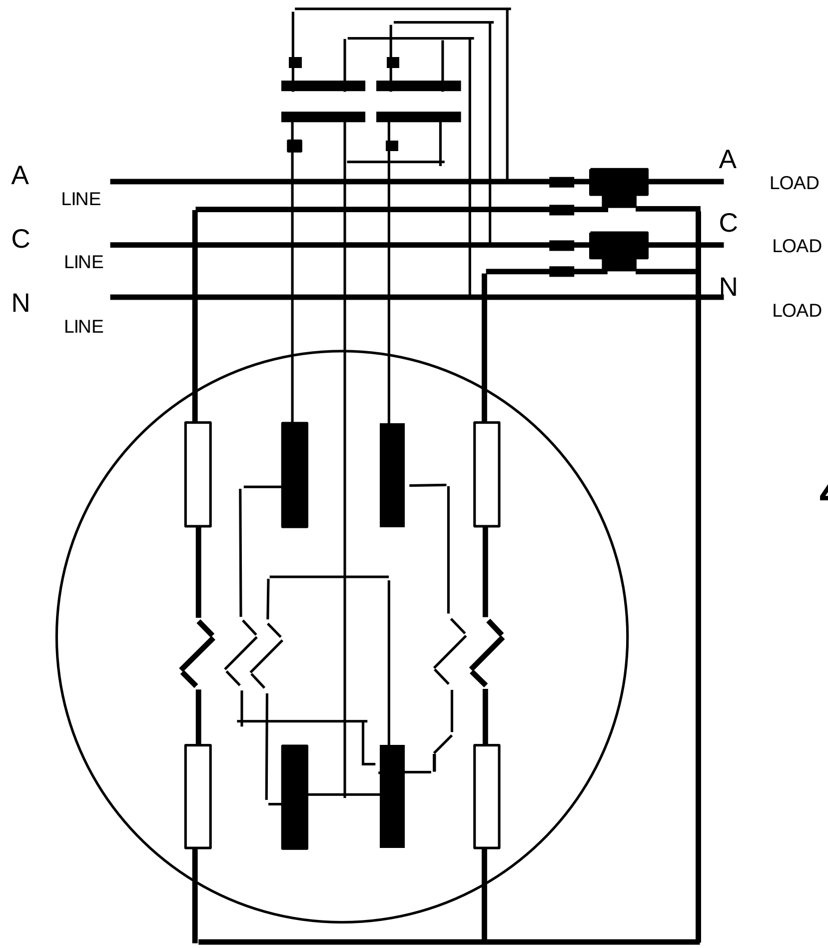
2 Element Meters



3 wire, network



3 wire, delta



45S

Polyphase Meters

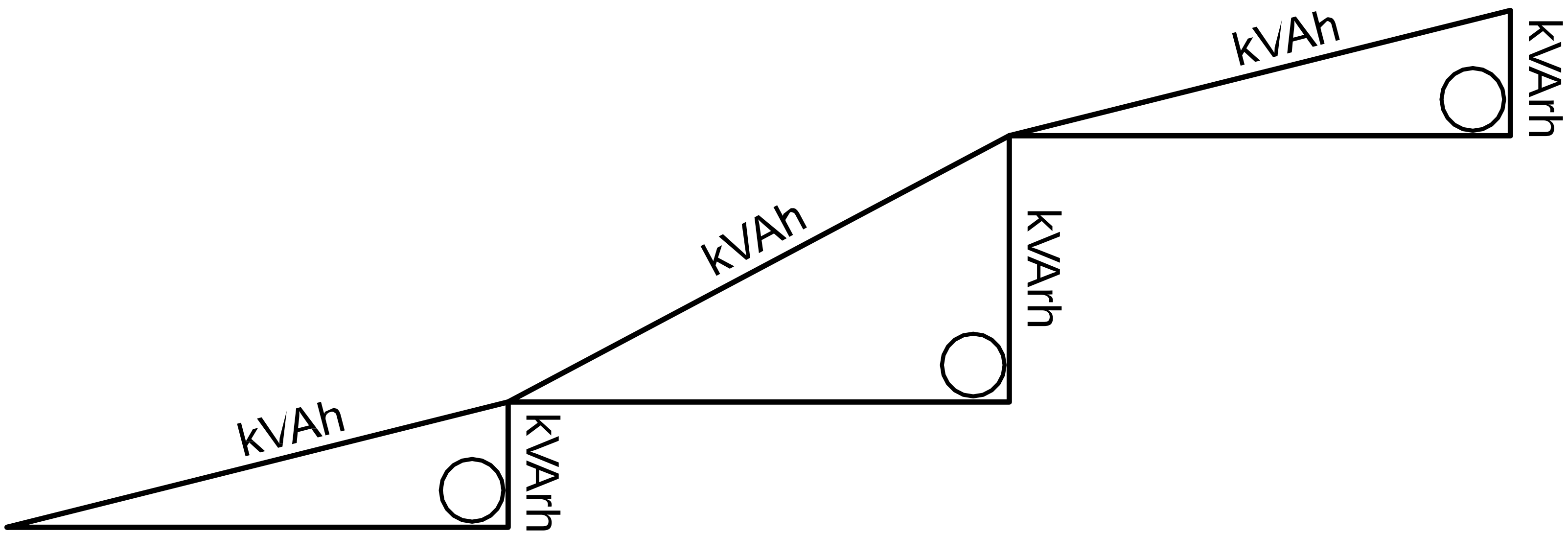
Other Considerations

- Meter Multipliers
  - Self Contained: The meter multiplier is 1
  - Transformer Rated: The multiplier is (typically) the product of the CT and VT ratio
- Service Types
  - Some polyphase meters may be used in multiple service types
- Selection
  - Proper wiring and form selection is critical

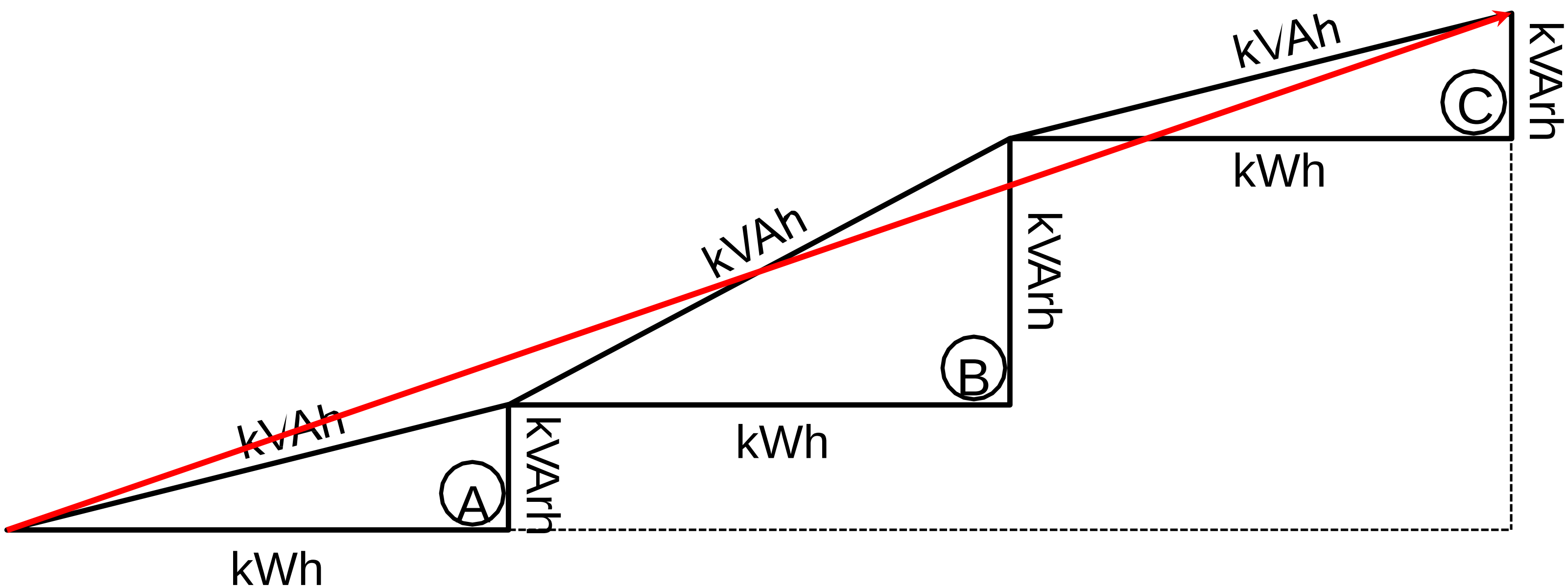
POLYPHASE METERS

- Select the meter based on the source, not the load.
  - The “service type” is not always obvious.
  - Loads other than the “known” load can be connected and may be unmetered.
- Meter form numbers describe certain meter characteristics not the service or application
- Consider that *ground* can be a current carrying conductor when applying Blondel’s Theorem.
- Understand the operation of present day, polyphase solid state meters and how they may be used to advantage

COMBINING POLYPHASE kVAh



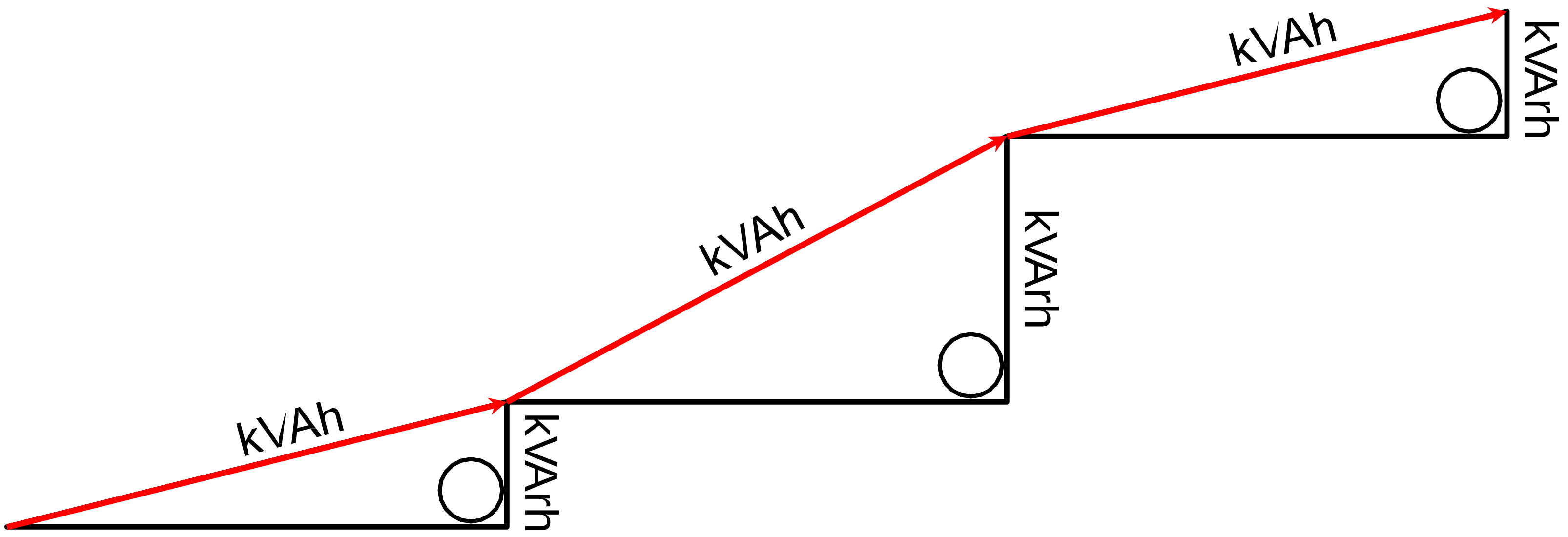
Combining Polyphase kVAh



Vectoral Method (as the crow flies):

$$\sqrt{(kWh_A + kWh_B + kWh_C)^2 + (kVArh_A + kVArh_B + kVArh_C)^2}$$

COMBINING POLYPHASE kVAh



Arithmetic Method:

$$\sqrt{kWh_A^2 + kVArh_A^2} + \sqrt{kWh_B^2 + kVArh_B^2} + \sqrt{kWh_{C_2} + kVArh_{C_2}}$$

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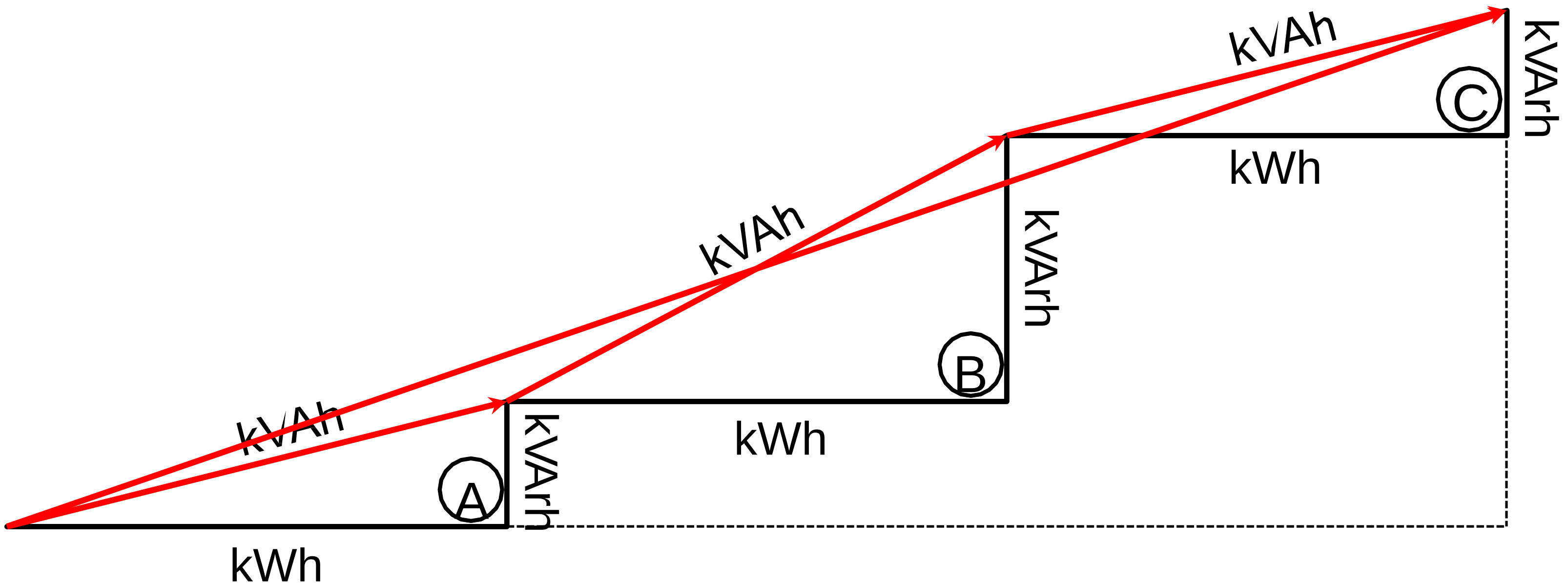
COMBINING POLYPHASE KVAH



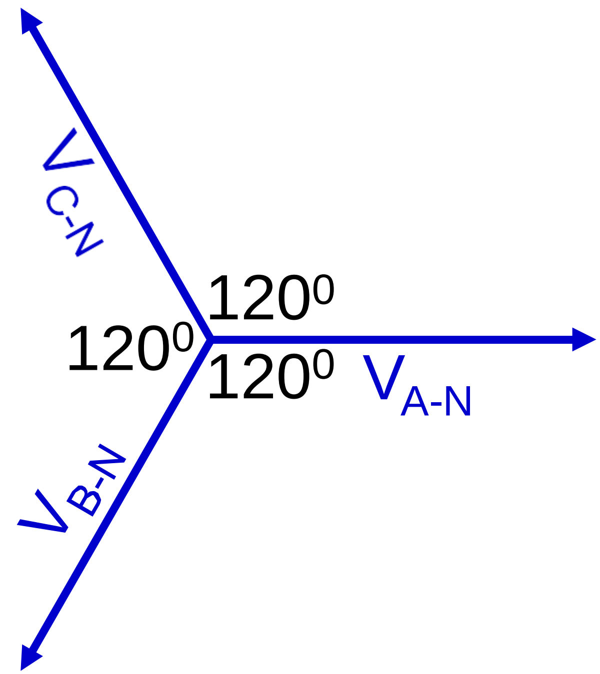
Arithmetically combined kVAh ≥ Vectorally combined kVAh

They are equal only if all phases have equal phase angles.

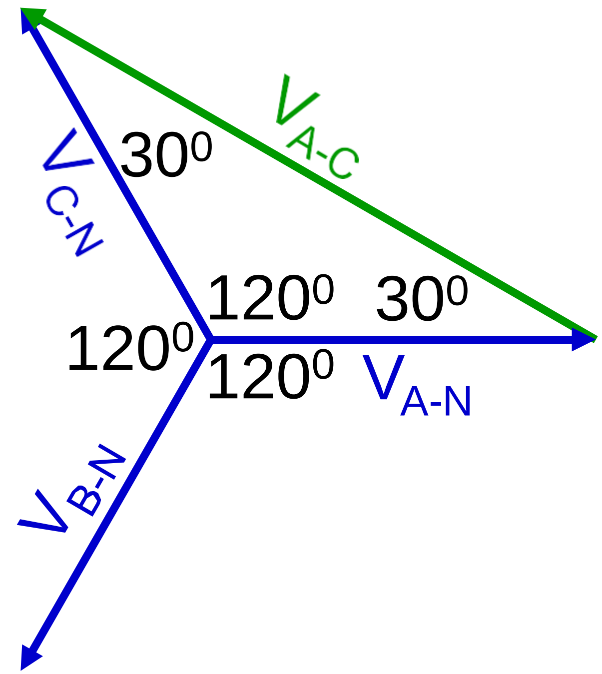
VOLTAGES IN A WYE-CONNECTION

$V_{L\text{-}L} = \sqrt{3}\ V_{L\text{-}N}$

We can prove this by constructing the Line-voltage (L-L) phasors based on the Phase-voltage (L-N) phasors.



Voltages in a Wye-Connection



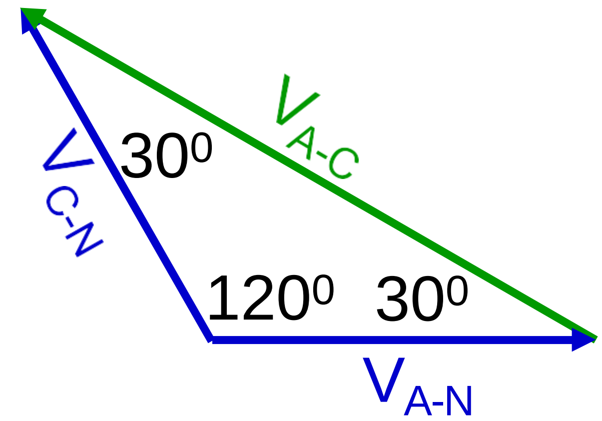
Voltages in a Wye-Connection

Using the Law of Sines:

$$\frac{V_{A\text{-}C}}{\text{sine } 120^0} = \frac{V_{A\text{-}N}}{\text{sine } 30^0}$$

$V_{A\text{-}C} = V_{A\text{-}N}$ sine 120^0 / sine 30^0

$V_{A\text{-}C} = \sqrt{3}\ V_{A\text{-}N}$



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Questions and Discussion

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